

UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 203

SEED PRODUCTION IN APPLES

By CHARLES S. CRANDALL



URBANA, ILLINOIS, AUGUST, 1917

SUMMARY OF BULLETIN No. 203

1. In this bulletin is recorded the seed production of four groups of apples, a total of 31,972 fruits: large apples of orchard varieties, 12,912; small apples of orchard varieties, 8,500; crabs, 6,642; and hand-pollinated fruits, 3,918.

2. Seed production in large apples exceeded that in small apples by 14.7 percent, and was nearly twice that recorded for crab fruits; the average seed production was, for large apples, 8.27; for small apples, 7.21; and for crab fruits, 4.22. Page 188

3. The minimum average seed content was 2.8, found in small fruits of Collins; the maximum average was 15.04, found in large fruits of Shockley. Page 188

4. Approximately 12 percent of the large fruits of orchard varieties contained the assumed normal of 10 seeds; 69 percent averaged below this normal, and about 18 percent above normal. Page 189

5. There was considerable variation in number of carpels; four orchard varieties held to the normal of five; all others showed departures from this normal. The range for large fruits was 4 to 8; for small fruits, 2 to 8. Page 191

6. Parthenocarpic fruits were found more often among small fruits than among large fruits of orchard varieties. Page 196

7. Percentages of ovules that developed as seeds were higher for groups of large apples than for small apples in twenty out of twenty-one varieties examined. Page 198

8. A test of extremes in size for one variety confirmed results from all varieties and strengthened the evidence that large apples develop a larger proportion of the ovules they contain than do small apples. Page 199

9. Crab fruits ranged in numbers of carpels from 2 to 12 and had a seed range of 0 to 14. Pages 205, 207

10. Production of ovules in excess of the expected normal occurred more frequently among orchard varieties than among crabs. Page 211

11. Control of pollination exercised no marked influence on numbers of seeds developed. Page 213

SEED PRODUCTION IN APPLES

By CHARLES S. CRANDALL, CHIEF IN PLANT BREEDING IN HORTICULTURE

INTRODUCTION

Each normal fruit of the common apple is made up of five centrally located carpels, each carpel forming one cell. Each of the five cells contains two ovules attached near the base to the perpendicular placenta, which is on the inner side of the cell, and hence central in the fruit. When all ovules are fertilized and develop into seeds, the full complement is ten for each normal apple.

Examination of a considerable number of apples brings out the fact that departures from the normal number of seeds are common and of all degrees, from an entire absence of developed seeds to an increase to more than two and one-half times the normal. Naturally these variations in the performance of individuals and varieties in the matter of seed production suggest questions regarding the factors governing fertilization and seed development, the relation of seed formation to size of fruit, and the possibility of developing a definite system of association of orchard varieties that would make for increase in fruit production. The development of such a system could not be accomplished in one year, nor in several years; it would require long and patient effort, but there can be no doubt that valuable scientific as well as economic results would attend its successful accomplishment. It is not the intention to enlarge upon this idea in the present publication, but simply to place on record observations that have been made relative to the actual seed production of groups of apple varieties grown under usual orchard conditions.

As a first step in a study of seed production in apples it is desirable to know something of the behavior of common orchard varieties in this regard. Do they live up to the possibilities in the matter of seed production? Do they fall short of, or do they exceed a definite normal? Are there well-defined differences in seed production that may rank as varietal characteristics? How do varieties producing very large fruits, Wolf River for example, compare in seed production with varieties producing small fruits, such as Red June or Lady? Within a variety, does any definite relation exist between size of fruit and seed content? These are some of the questions that are suggested at the outset of the inquiry.

OPINIONS REGARDING SEED PRODUCTION

Horticultural literature, so far as consulted, yields little information concerning the questions here suggested. Seed production in apples appears to have been passed over. There are no records

of extended investigation and only meager references to the performance of this fruit in this particular. There do appear certain statements indicating common belief in a general principle that with seed-bearing plants, and especially with economic fruit plants, in which there is large development of edible parts, there is a corresponding diminution in seed-producing capacity; or, to state it more definitely, fruits with highly developed fleshy parts produce fewer seeds than do those fruits in which the fleshy parts are not enlarged.

The development of seeds, the forming of the embryos, and the storing of food necessary for the young plants form an exhaustive process drawing heavily upon the resources of the plant. It is a perfectly natural conclusion that the production of full complements of seeds and the storing of large quantities of edible fruit flesh are antagonistic and that large size and full seed production are not likely to be at a maximum in the same fruits.

In discussing compensation and economy of growth, Darwin¹ makes this general statement:

"When the seeds in our fruits become atrophied, the fruit itself gains largely in size and quality."

Lindley says²:

"Sterility is a common malady of cultivated plants, the finer varieties of fruit, and all double and highly cultivated flowers, being more frequently barren than fertile. This arises from several causes. The most common cause of sterility is an unnatural development of some organ in the vicinity of the seed, which attracts to itself the organizable matter that would otherwise be applicable to the support of the seed. Of this the Pear, the Pineapple, and the Plantain are illustrative instances."

E. L. Sturtevant³ affirms that small fruits contain more developed seeds than do large fruits. He writes as follows:

"The better varieties of the apple usually contain some abortive seeds and are sometimes individually to be found seedless. As a rule, where there is a tendency to abortive seeds, the larger and finer the apple the greater the number of abortive seeds. Thus five Baldwin apples, weighing thirty ounces, had eleven plump and nine shriveled seeds; five others from the same barrel, and weighing seventeen ounces, furnished twenty-five plump and three abortive seeds."

Dr. Sturtevant's conclusion appears to be based upon examination of 145 apples representing thirty-five varieties. One variety, the Baldwin, was represented by sixty-seven apples; of the others, eighteen had one fruit each, four had two each, and twelve had numbers of fruits from three to eight. The average number of good seeds was 5.67; the minimum number found was one each in Newtown Pippin and Gray Russet; the maximum was 12.75 in Northern Spy. The numbers of fruits examined, however, were too small, at least for all varieties except Baldwin, to serve as a good index of the seed-producing capacities of the varieties.

¹Origin of Species, 6th ed., p. 139.

²Theory of Horticulture, Downing, 2d. ed. (1852), p. 170.

³On Seedless Fruits, Mem. Torrey Bot. Club, 1, No. 4 (1890), p. 145.

The authors quoted do not state the converse of the principle laid down, but each leaves the reader to infer that fruits not highly developed, those in or near the wild state, while deficient in flesh, the part valuable to man, excel in seed production.

Bailey¹ expresses a view contrary to that given by the writers quoted above. He says:

"As a rule, the cultivated varieties of apples contain more seeds than the wild apples of Europe do. Forty specimens of the wild crab (*Pyrus Malus*) of central Europe produced an aggregate of two hundred fifty-six seeds, or an average of six and two-fifths seeds to each fruit. Forty Northern Spys contained four hundred eighty-one seeds, or an average of twelve and one-fortieth to the fruit. Normally, the apple should contain ten seeds, two to each carpel, but some of these Spys had fifteen seeds and one had eighteen. Yet some other varieties of apples contain fewer than the normal number, while some are almost entirely seedless. There is generally a slight increase in seed production as fruits develop away from the first type, especially if the fruits become larger. This is a natural consequence of the increase in size, tho it bears no constant ratio to this increase."

SEED-PRODUCTION RECORDS

As a basis from which to judge the performance of apples and crabs in seed production when varieties are grown in mixed plantations and left open for undisturbed visitation by insects, records were taken from 28,054 individual apples. Thirty-two orchard varieties were represented by 21,412 fruits, and twenty-five species and varieties of the genus *Malus* were represented by 6,642 fruits. This latter is a strictly crab group; none of the species or varieties have any economic value other than as ornamentals. They vary widely among themselves and represent several types, but all closely approximate the wild originals.

With the exception of Garfield and Twenty Ounce, varieties represented by small numbers of fruits very uniform in size, the fruits of each orchard variety were divided into two groups on the basis of size, a group of large apples and a group of small apples, in order to determine whether or not there is constant difference in seed production between groups thus separated. Transverse diameter was taken as the basis of division. In a few varieties all fruits 65 mm. or above in diameter were classed as large, all below that dimension as small. In most varieties, however, it was possible to leave a gap of from 3 to 10 mm. between groups and in that way make them more distinct; thus, in several varieties the maximum for the group of small apples was 70 mm., and the minimum for the group of large apples, 75 mm.

In the crab group there prevailed such uniformity in the size of fruit within each species or variety that no division into size-groups was attempted.

Records obtained from the fruits examined support the view that the more highly developed fruits, that is to say, such fruits as are

¹The Survival of the Unlike (1901), p. 253.

produced by varieties commonly grown in orchards, develop seeds in greater numbers than do the crab-like fruits of less highly developed forms of the genus *Malus*. A further fact developed from the records was that in nearly all the varieties, the fruits of which were divided into size-groups, the groups containing large apples produced more seeds than did the groups containing small apples. The differences between these three classes of fruits in average seed production are as follows:

1. Average seeds to the fruit for 12,912 apples of large size, representing thirty-two varieties, 8.27.
2. Average seeds to the fruit for 8,500 apples of small size, representing thirty varieties, 7.21.
3. Average seeds to the fruit for 6,642 apples, representing twenty-five crab-like forms of *Malus*, 4.22.

Here the average for large orchard fruits exceeds the average for small orchard fruits by 14.7 percent, and is very nearly twice as great as for the crab-like forms.

In each of the three groups for which average seed production is given there was a wide range between maximum and minimum seed production as exhibited by the different varieties and species. Thus, among the groups of large fruits, Collins was the least productive, the average for 261 fruits being 4.09 seeds, and Shockley the most productive, with an average for 177 fruits of 15.04 seeds. In the groups of small fruits, Collins was again the least productive, with an average for 150 apples of 2.8 seeds: the maximum here, as in the groups of large fruits, falls to Shockley, which, for 177 apples, had an average of 14.59 seeds.

In the crab group the lowest in seed production was *Malus fusca*, with an average of 1.32 seeds to each fruit, but this species was represented by so few fruits that this average is not regarded as dependable for the species. The next lowest was *Malus atrosanguinea*, which, for the 100 fruits examined, had an average of 2.02 seeds to each fruit. The most productive in this group was *Malus Malus flore pleno*, which, for 100 fruits, had an average of 7.8 seeds to each fruit. The second in seed production was *Malus microcarpa*, which, for 100 fruits, had an average of 7.09 seeds to each fruit.

Between the extremes in seed production given for the different classes of fruits the averages were various: no two were alike, but the majority tended towards approximation of the general average for the class. High seed production appeared to be characteristic of some orchard varieties, while certain others of these varieties were equally constant in low production. Some varieties tended to concentrate within the normal of ten seeds, as was the case with Arkansas Black, Grimes, Fameuse, and Rome; others tended to scatter the production over a wide range, as 1 to 27 in Shockley, 3 to 21 in Rhenish May, and 3 to 19 in Winter Rambo. In the groups of apples

TABLE 1.—S_E[illegible]

of large size, no fruits had less than four seeds in Garfield, Osceola, Polische Jungfrau, and Wythe; none had less than three in Crawford, Rhenish May, Smith Cider, Willow, Winesap, and Winter Rambo.

Seedless apples occurred in the large size-groups of McMahon and Twenty Ounce, in both size-groups of Ben Davis, Collins, Golden Ball, Minkler, and Wealthy, and in the small size-groups of Bailey Sweet, Indian, Jonathan, Isham, Osceola, Rhenish May, Shockley, Tolman, and Winesap; they occurred rather more frequently among small apples than among large. Seedless apples will be referred to again in connection with detailed accounts of the several classes of fruits.

ORCHARD VARIETIES

Records of numbers of carpels and distribution of seeds for the two size-groups of orchard varieties are brought together in tabular form in Tables 1 and 2. Records of ovule production of the orchard varieties are presented in Table 7.

Distribution of seed production in its relation to the full normal content of ten seeds is of interest as showing the extent of departures from the normal in both directions. Considering the apples according to the classes into which they have been divided, the apples of large size as produced by orchard varieties may come first.

SEED DISTRIBUTION OF APPLES OF LARGE SIZE

The apples of large size included thirty-two varietal groups, aggregating 12,912 apples; they produced 106,845 seeds, an average of 8.27 seeds to each fruit. The number of apples producing the normal of ten seeds was 1,610, or 12.5 percent of the whole number. These apples bore 16,100 seeds, or approximately 15 percent of the number of seeds produced by all fruits of the group. The number of apples falling below normal in seed production was 8,913, or 69 percent of the total; these apples bore 58,412 seeds, or 54.67 percent of the total produced by fruits of this class. With seed production above normal there remained 2,389 apples, or 18.5 percent of the total; these bore 32,333 seeds, or 30.26 percent of the total seeds.

SEED DISTRIBUTION OF APPLES OF SMALL SIZE

The groups of small apples represented thirty varieties, and together contained 8,500 apples which produced 61,325 seeds, an average of 7.21 to each fruit. The number of apples producing the normal of ten seeds was 1,020, or 12 percent of the total; these produced 10,200 seeds, or 16.63 percent of the total. The number of apples producing less than ten seeds was 6,786, or 79.84 percent of the total; these produced 42,178 seeds, or 68.78 percent of the seeds produced by the

group. The number of apples with seeds ranging above ten was 694, or 8.16 percent: these produced 8,947 seeds, or 14.59 percent of the seed total.

COMPARISON OF SEED DISTRIBUTION OF THE TWO SIZE-GROUPS

Comparing the size-groups, it is seen that the percentages of fruits having the normal number of ten seeds were nearly the same, 12.5 percent for the large and 12 percent for the small. In numbers of fruits having seeds in excess of ten the large fruits lead by a considerable margin; the percentages were 18.5 for large and 8.16 for small. Of fruits with less than the normal number of seeds, small fruits had the greatest numbers, nearly 80 percent as compared with 69 percent for large fruits. Seedless fruits numbered 37 among large apples and 64 among small apples. Apples having one seed each numbered 93 for the groups of large apples and 121 for the groups of small apples. With two seeds each there were 231 large apples and 277 small apples; from this there was a gradual increase in number of apples with each addition to the seeds to each fruit, until the maximum of 1,843 apples of large size and 1,257 apples of small size was reached with nine seeds to each fruit. Above this the decline in numbers was rapid for both classes, but there were still a considerable number of apples having large excess in numbers of seeds. Thus, 95 large apples had eighteen seeds each, 48 had nineteen each, and 36 had twenty or above. Among small apples, 16 had eighteen seeds each, 11 had nineteen each, and 27 had twenty or above.

NUMBER AND DISTRIBUTION OF CARPELS

The number of carpels in a normal apple is five, but just as there are more or less frequent abnormalities in number of floral parts, sepals, petals, and stamens, so there are departures from the normal in number of cells in the compound ovary. Among fruits of orchard varieties examined there were found 789 apples, or 3.68 percent of the total number, that departed from the normal in number of cells. Increase in number was much more frequent than diminution; 129 fruits had less than five cells and 660 had more than five.

Distribution of the abnormalities among varieties was not at all uniform. Winter Rambo had more than any other variety, 243 out of 1,050 apples, or 23.14 percent: 1 fruit had four cells, 186 had six cells, 50 had seven cells, and 6 had eight cells, while 807 were normal with five cells each. Rhenish May had the next largest number of fruits showing departures from normal, 219, but because of the larger number of apples examined the percentage was only 6.42, much lower than for Winter Rambo. In this variety there were 8 fruits with three cells each, 50 with four cells, 160 with six cells, and 1 with seven

cells. Huntsman had the third largest number of abnormalities, with 130 six-celled fruits and 2 having seven cells each. This variety was represented by 1,261 apples, and the percentage of departures from normal was 10.46. Numbers of fruits with other than normal cells were very much smaller for the remaining twenty-five varieties among which they were distributed. Five of these varieties, Bailey Sweet, Grimes, Osceola, Twenty Ounce, and Wolf River, with an aggregate of 1,911 apples, had each one six-celled fruit, all others being five-celled. Four varieties, Indian, Isham, Jonathan, and Shockley, with a total of 1,606 apples, had only five-celled fruits.

As between the two size-groups, large and small, there was very little difference in the frequency with which abnormalities in cells appeared. In the group of large apples there were 474 fruits having cells above or below the normal number; in the group of small apples the number was 315, but large apples were more numerous than small and the ratio of abnormalities was practically equal for the two groups.

VARIETIES HIGH IN SEED PRODUCTION

Certain of our varieties exhibited an exceptionally strong tendency to multiplication of seeds; at least three of these, Winter Rambo, Rhenish May, and Shockley, are perhaps worthy of individual consideration.

WINTER RAMBO

In the large size-group of Winter Rambo were four apples, each with eight cells containing plump and abortive seeds, as follows: 10-6, 16-3, 11-5, and 12-4. In the second of these fruits there was an addition of three to the expected number of ovules. Irregularity in number of ovules appeared to be characteristic of this variety; the range was from the normal of 10 for a five-celled fruit to 24 for a six-celled fruit. One of the fruits examined had six cells with 4 ovules in each cell, 19 of which developed into seeds. Of 550 Winter Rambo apples of large size, 35, or more than 6 percent, had each seven cells. These apples contained 565 ovules, an average of 16.14. The expected total of ovules in 35 seven-celled apples is 490; hence there was here an excess of over 15 percent. The seeds that developed numbered 411; this represents 72.75 percent of the ovules present, but falls a little more than 16 percent below the full complement for 35 seven-celled fruits. The lowest seed production in these fruits was six in one fruit having 14 ovules; the maximum production was seventeen seeds in a fruit having 17 ovules. The maximum seed production in this variety falls to two six-celled apples, one of which had 19 ovules, all of which formed good, plump seeds; the other had 24 ovules, 19 of which became fully developed seeds. At the other extreme were two

fruits with three seeds each, both having the expected number of ovules, one fruit five-celled, the other six-celled.

In this variety there were considerable differences between large fruits and small fruits in number and distribution of seeds. These differences are best shown by a direct comparison of the distribution percentages presented in Table 3.

TABLE 3.—DISTRIBUTION OF SEEDS IN LARGE AND SMALL WINTER RAMBO APPLES

Size-group	Number of apples	Distribution of seeds			Average seed content
		Percentage normal	Percentage below normal	Percentage above normal	
Large.....	550	17.09	45.64	37.27	9.98
Small.....	500	13.80	72.00	14.20	8.30

NOTE.—Normal is here taken to be ten seeds to each five-celled fruit.

The large fruits exceeded the small fruits by more than 20 percent in average of seeds to each fruit and by more than 32 percent in number of seeds produced. The fruits having seeds in excess of the normal were nearly three times as numerous in the group of large apples as in the group of small apples, while of the apples below normal in seed production the small apples exceeded the large by about 35 percent. In this variety, then, it is evident that the large fruits were greater seed producers than were the small fruits.

RHENISH MAY

The second of the three varieties showing greatest tendency to multiplication of seeds was Rhenish May, in which the large size-group was represented by 2,398 apples and the small size-group by 1,009 apples. For the large apples the average seed production was 11.65 and for the small apples 7.55. Ten percent of the large apples contained ten seeds each and produced 9 percent of the seed total for large apples; 30 percent had numbers of seeds below ten and carried 19 percent of the total number of seeds, while 60 percent of the fruits had seeds in excess of ten and carried 72 percent of the seeds. In the group of small apples the percentage of fruits having the normal of ten seeds each was 10, the same as for the large apples, and they had 13.3 percent of the seeds borne by the group. The percentage of fruits with less than ten seeds was very much greater than for the large fruits, 72.4 percent as against 30 percent for the large fruits, and these carried 58.1 percent of all the seeds. Only 17.6 percent of this group had above ten seeds each, but they produced 28.6 percent of the total number of seeds. The superiority of large apples as compared with small apples in seed production was as well defined in Rhenish May as in Winter Rambo. In Table 4 are presented the figures for seed distribution in Rhenish May.

TABLE 4.—DISTRIBUTION OF SEEDS IN LARGE AND SMALL RHENISH MAY APPLES

Size-groups	Number of apples	Distribution of seeds						Average seed content
		Normal		Below normal		Above normal		
		Percent	Per-centage of total	Percent	Per-centage of total	Percent	Per-centage of total	
Large...	2398	10	9.0	30.0	19.0	60.0	72.0	11.65
Small...	1009	10	13.3	72.4	58.1	17.6	28.6	7.55

SHOCKLEY

The third of the three varieties standing highest in seed production was Shockley. The multiplication of seeds in this variety was so pronounced that it was really in a class by itself. As with other varieties, the fruits were divided into two size-groups; each group contained 177 apples. There were no departures from normal in number of cells; each fruit had five. Unlike the other varieties there was, in Shockley, but very little difference in seed distribution between large apples and small apples. The tendency to multiplication was about the same in all fruits, and appeared as a well-established varietal characteristic. Averages of seeds to each fruit and seed distribution are shown in Table 5.

TABLE 5.—DISTRIBUTION OF SEEDS IN LARGE AND SMALL SHOCKLEY APPLES

Size-groups	Number of apples	Distribution of seeds						Average seed content
		Normal		Below normal		Above normal		
		Number	Percent	Number	Percent	Number	Percent	
Large...	177	4	2.26	21	11.86	152	85.88	15.04
Small...	177	7	3.96	19	10.73	151	85.31	14.59

The total number of ovules in all fruits was 6,536, an average of 18.5 for each fruit. As between the two size-groups, the large apples had 3,298, or 50.5 percent, and the small apples 3,238, or 49.5 percent, a nearly equal distribution. Of the total ovules 80.3 percent developed into seeds; and here, also, the division between large and small fruits approximated equality. The lowest number of ovules in any fruit was 10 in one small fruit. Three large fruits and one small fruit had each 11 ovules, and two large and five small had each 12. At the other extreme, one large fruit had 27 ovules, 21 of which developed into seeds, and one small fruit had 27 ovules, all of which became seeds. Two large fruits had each 26 ovules: one of these developed 24 seeds, the other 22. Four fruits had 25 ovules each with an average of 21 seeds. The maximum frequency of ovules falls on 20, there being thirty-one large apples and thirty-six small apples having each

this number. These apples having 20 ovules each showed wide range in seed development. Of the large fruits, one had 1 seed, one had 2, and one had 5; and at the other extreme, three developed the total of 20 each, two had 19 each, and five had 18 each. Among the small apples having 20 ovules, four had no seeds; one had 11 seeds, two had 13 each, and nine had the full complement of 20 each. Aside from the four apples just referred to as having 20 ovules each and no developed seeds, were two others in the same group that were seedless; one of these had 17 ovules, the other 15. Some of the ovules in these six seedless fruits had enlarged the integuments somewhat, but none approached the size of mature seeds and all were perfectly flat, with nothing to indicate any activity in the direction of embryo development.

In order to indicate the position with regard to the size and weight of these parthenocarpic fruits as compared with other apples of the same group that stand high in seed production, six apples, each having twenty ovules, all represented by apparently perfect seeds, were taken at random and are shown in comparison with six seedless fruits in Table 6.

TABLE 6.—COMPARISON OF SEEDLESS FRUITS WITH FRUITS OF HIGH SEED PRODUCTION AS TO SIZE AND WEIGHT: SHOCKLEY

	Aver. weight in grams	Aver. diameter (mm.)	
		Long	Transverse
Six seedless fruits.....	102.75	49	64
Six fruits with 20 seeds each.....	94.49	51	58

It here appears that the parthenocarpic fruits were not the smallest in the group, as they exceeded an equal number of fruits that were highly productive of seeds, both in weight and in transverse diameter. The stimulus of the assumed pollination developed fruits of good size in the absence of fertilization. Fig. 1 shows abnormal seed production in Shockley.

HUNTSMAN

One other variety may be referred to here, the Huntsman, not so much because of its high seed content, altho one fruit reached a maximum of 18 seeds, but because of the symmetry of parts, the very open character of the core, the size and uniformity of cells, and the breadth of carpels. The variety was represented by 731 large fruits and 530 small. The average seed content of the large apples was 7.97; of the small apples, 6.66. Over 11 percent of the fruits had 11 or more seeds each, bringing the variety to fourth place on the list in this particular. It was exceeded by Shockley, Rhenish May, and

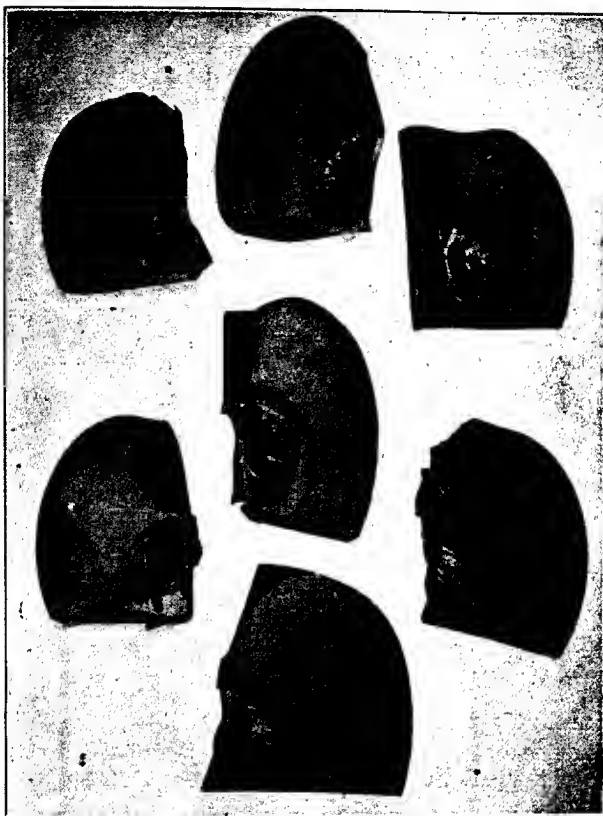


FIG. 1.—SEED PRODUCTION IN SHOCKLEY. PORTIONS OF FRUITS SHOWING NUMBER AND ARRANGEMENT OF SEEDS IN VARIOUS CARPELS

Winter Rambo, percentages for which have been given. The one fruit that had 18 seeds was photographed in section to show regularity of cells and high seed content; there were six cells, each with 3 plump seeds. This apple weighed 156 grams, and measured 54 mm. in longitudinal diameter and 72 mm. in transverse diameter. A section of the fruit appears in the front cover illustration.

VARIETIES LOW IN SEED PRODUCTION

Of the least productive varieties, Collins had the lowest seed content of any of the varieties examined. The 261 large apples had an

average of 4.09 seeds; the maximum of nine was reached by 5 fruits, 16 fruits had only one seed each, and 48 had two each; three were seedless. The 150 small apples averaged 2.8 seeds; this was the lowest average found for any group. Four fruits had seven seeds each; this was the maximum for the group. Twenty-two had one seed each; 40 had two each, and 12 fruits were seedless. The apples of this small size-group were well above the size limit for No. 1 apples, as is shown by the average transverse diameter of 68 mm. and by the average weight, 134 grams.

Next above Collins in seed production was Minkler. In the large size-group of this variety there were 863 apples, which produced 3,694 seeds, an average of 4.28 to each fruit: 4 fruits had each the maximum of ten seeds, 55 had one seed each, 99 had two seeds each, and 20 were without seeds. The apples of this group had an average transverse diameter of 73.31 mm., and the average weight was 170.85 grams.

The small size-group numbered only 54 apples with an average of 3.65 seeds to each apple: two fruits had eight seeds each, the maximum for the group, and three fruits were seedless.

SEED PRODUCTION IN THE REMAINING VARIETIES .

The twenty-six varieties that have not been specifically mentioned had various seed averages. In fourteen of them the range of averages was between 5 and 8 seeds to each fruit and in twelve it was between 8 and 11. With two exceptions the groups of large apples had distinctively greater seed averages than the groups of small apples. The two exceptions were Shockley, already mentioned in detail, in which the difference in size-groups was very slight, and McMahon. In this latter variety the number of apples was 200 for each group. The group of large apples had an average of 7 seeds to each fruit and the group of small apples an average of 7.75 seeds. The small apples also reached a higher maximum: two fruits had 14 seeds each, while only one fruit, in the group of large apples, reached a maximum of 13.

SIZE OF FRUIT IN RELATION TO THE PERCENTAGE OF OVULES DEVELOPED AS SEEDS

Another method of determining the relative seed production of large apples and small apples is by comparing the number of developed seeds in each of the two groups for each variety. Records obtained from twenty-one varieties are presented in Table 7, showing for each size-group the number of apples, the number of cells, the normal ovule content, allowing two to each cell, the number of ovules actually present, the excess above normal, the number of good seeds, the aborted seeds, and the percentage of ovules actually present that developed as seeds.

TABLE 7.—OVULE PRODUCTION IN ORCHARD VARIETIES

Variety	Number of apples	Number of carpels	Ovules					Percentage developed
			Normal number	Number found	Excess	Number developed	Number undeveloped	
Large Apples								
Bailey Sweet.....	200	1001	2002	2288	286	1846	442	80.68
Collins.....	261	1303	2606	2606	...	1067	1539	40.94
Crawford.....	200	989	1978	2019	41	1294	725	64.09
Fameuse.....	200	1000	2000	2003	3	1303	700	65.05
Golden Ball.....	200	1002	2004	2114	110	1888	226	89.31
Hibernal.....	200	1000	2000	2008	8	1192	816	59.36
Indian.....	200	1000	2000	2156	156	1430	726	66.32
Isham.....	200	1000	2000	2052	52	1180	872	57.50
Mammoth Black Twig...	200	1001	2002	2002	...	1036	966	51.74
McClellan.....	200	999	1998	2010	12	1627	383	80.94
McMahon.....	200	998	1996	2208	212	1400	808	63.40
Osceola.....	200	1001	2002	2157	155	1862	295	86.32
Polische Jungfrau.....	200	1002	2004	2339	335	2073	266	88.62
Rome.....	200	1002	2004	2029	25	1479	550	72.89
Shockley.....	177	885	1770	3298	1528	2665	633	80.80
Tolman.....	200	1004	2008	2034	26	1628	406	80.03
Wealthy.....	513	2566	5132	5135	3	4260	875	82.96
Willow.....	150	788	1576	1595	19	1235	360	77.43
Winter Rambo.....	550	2950	5900	6778	878	5488	1290	80.96
Wolf River.....	200	1001	2002	2167	165	1823	344	84.12
Wythe.....	200	1000	2000	2321	321	1948	373	68.92
Total.....	4851	24492	48984	53319	4335	39724	13595	74.50 ¹
Small Apples								
Bailey Sweet.....	199	995	1990	2117	127	1645	472	77.70
Collins.....	150	742	1484	1484	...	420	1064	28.30
Crawford.....	200	979	1958	1979	21	1051	928	53.10
Fameuse.....	200	1000	2000	2002	2	1036	966	51.74
Golden Ball.....	200	1001	2002	2066	64	1794	272	86.83
Hibernal.....	200	998	1996	2011	15	1148	863	57.08
Indian.....	200	1000	2000	2020	20	809	1211	40.04
Isham.....	200	1000	2000	2036	26	1066	960	52.61
Mammoth Black Twig...	200	997	1994	1994	...	724	1270	36.30
McClellan.....	200	999	1998	2004	6	1498	506	74.75
McMahon.....	200	998	1996	2295	299	1551	744	67.58
Osceola.....	200	1000	2000	2014	14	1341	673	66.56
Polische Jungfrau.....	200	1001	2002	2149	147	1729	420	80.46
Rome.....	200	1000	2000	2009	9	1196	813	59.53
Shockley.....	177	885	1770	3238	1468	2584	654	79.80
Tolman.....	200	1003	2006	2006	...	1362	644	67.89
Wealthy.....	500	2498	4996	5002	6	3978	1024	79.52
Willow.....	200	1026	2052	2113	61	1558	555	73.73
Winter Rambo.....	500	2603	5206	5540	334	4148	1392	74.87
Wolf River.....	200	1000	2000	2150	150	1629	521	75.76
Wythe.....	200	999	1998	2166	168	1673	493	77.23
Total.....	4726	23724	47448	50385	2937	33940	16445	67.36 ¹

¹Average.

The number of large apples was 4,851; of small apples, 4,726. In all but three of the varieties the numbers of ovules present in the groups of large fruits were higher than in the groups of small fruits. The exceptions to the rule were: Hibernial, in which variety the 200 fruits in the small size-group had three more ovules than had the 200 apples in the large size-group, a difference so small as to bring the groups practically to equality; MacMahon, in which the group of small apples exceeded the large in total number of ovules by eighty-seven; and Willow, in which, taking into consideration the fact that the group of small apples exceeded the large by fifty in number of fruits, there was an excess of thirteen ovules for the small group. Of those varieties in which large apples exceeded small apples in numbers of ovules, Fameuse had the least difference and Winter Rambo the greatest. The average difference for all varieties approximated one hundred.

Some varieties exhibited little tendency to increase in number of ovules above the normal; others had the tendency strongly marked. In Collins and Mammoth Black Twig there was no excess in either size-group; in Tolman there was no excess in the small size-group, but an excess of twenty-six in the large size-group. All others had some excess in both groups, ranging, in the groups of large apples, from three for Fameuse and Wealthy to 1,528 for Shockley, and in the groups of small apples, from two for Fameuse to 1,468 for Shockley.

The percentages of ovules found present that were followed by plump and apparently viable seeds are, perhaps, the best gage of the relative seed-producing capabilities of the large and the small apples. Of the twenty-one varieties under consideration, all but one had the higher percentages of seeds developed in the groups of large apples. The one exception was McMahon, which had 63 percent of the ovules developed into good seeds in the group of large apples, and 68 percent thus developed in the group of small fruits. Percentages for the list of varieties other than McMahon ranged, for the groups of large apples, from 41 percent for Collins to 89 percent for Golden Ball. Half the varieties had percentages of 80 or above; others were somewhat less, but the average for the twenty varieties was 75 percent. On the other hand, the range of percentages of plump seeds for the groups of small apples was between 28 for Collins and 87 for Golden Ball, with an average for the twenty varieties of 67. In some varieties the differences between groups were small, as for example, Hibernial with a percentage of 59 for large apples and 57 for small, or Shockley with 81 percent for large and 80 percent for small. In others the differences were considerable, as in Mammoth Black Twig with 52 percent for large and 36 percent for small, or Indian with 66 percent for large and 40 percent for small. For the small apples of the twenty varieties taken together, the average of seeds developed was 67 percent of the possible as against 75 percent for the large apples.

In separating large apples from small apples for the groups considered above, a gap of 5 mm. was left between, that is to say, the minimum transverse diameter admitted to the group of large apples was 5 mm. more than the maximum transverse diameter included in the group of small apples. To test the effect of greater size difference between groups, the 100 largest Winter Rambo apples were selected for comparison with the 100 smallest of the same variety. The original groups of Winter Rambo numbered 550 large and 500 small, a sufficient number for a fair test of extremes.

These selected centenary groups ranged in transverse diameters as follows: the large apples from a minimum of 72 mm. to a maximum of 87 mm., with an average of 75 mm.; the small apples from a minimum of 40 mm. to a maximum of 52 mm., with an average of 48 mm.; the gap between groups was 20 mm., and the averages differed by 27 mm. The averages for the groups are tabulated below:

TABLE 8.—COMPARISON OF CENTENARY GROUPS OF LARGE AND SMALL
WINTER RAMBO APPLES

Size-group	Aver. weight in grams	Average diameter in mm.		Aver. No. good seeds	Aver. No. undevel- oped ovules	Percentage of ovules forming seeds
		Long	Transverse			
Large.....	167	59	75	10.64	2.53	81
Small.....	67	39	48	6.49	3.24	67

In the original group of 550 large apples the average seed content was 9.98; in this group restricted to the 100 largest it was 10.64, an increase of nearly 7 percent, and there was a corresponding increase in the number of ovules that did not develop. The percentage of ovules forming seeds was the same in both groups.

In the group of 500 small apples the average seed content was 8.3. The 100 smallest apples of this group had a seed average of 6.49, nearly 22 percent less than that of the full group. The increase in undeveloped ovules was over 14 percent and the decrease in percentage of seeds formed was about 8 percent. As between the centenary groups, the percentages of ovules developing into good seeds were 81 for the large apples and 67 for the small apples.

This comparison between the extremes in size found in apples of one variety confirms the results obtained in the analysis of seed production for all the varieties and strengthens the evidence which, taken together, appears to establish the fact that large apples develop a considerably larger proportion of the ovules they contain than do small apples.

In Table 7 is reported the ovule production of twenty-one varieties represented by 9,577 apples nearly equally divided into two groups

on the basis of size. Examination in detail of the ovule and seed content of these apples indicates in a positive way that large apples are superior to small apples in seed production. The large apples contained nearly 6 percent more ovules than did the small apples, the total of seeds produced was 17 percent greater, and the percentages of ovules developed into seeds were, with the one exception cited, higher for the groups of large apples than for those of small apples.

SPECIES OF MALUS

The fruiting forms of the genus *Malus* included in the record of seed production number twenty-five. They represent seventeen named species and six classed as varieties, besides two, the Hyslop and Yellow Siberian Crabs, carried under their common names. There is much confusion in the nomenclature of the species of the genus and the taxonomic rank of some of our forms is uncertain, and cannot be definitely determined until a complete monograph of the genus is available. Three of the forms, namely, *Malus Ioensis*, the wild crab of the middle west, *Malus Soultardi*, the Soultard Crab, and *Malus fusca*, the Oregon Crab, are native. *Malus Arnoldiana* is a seedling of *Malus floribunda* originated at the Arnold Arboretum several years ago. *Malus prunifolia* var. (856) also originated at the Arnold Arboretum from seed collected in Japan in 1892 by Dr. C. S. Sargent. The names with descriptions of these two have not yet been published, but doubtless will be in the near future. It is probable that one or two of the other forms are seedlings having origin in this country, but with these definite and possible exceptions the forms in the list are of European or Asiatic origin.

The fruits of each species or variety were weighed and the average weight was recorded. Each individual was measured with calipers for longitudinal and transverse diameters. It was then cut transversely and record made of the number of carpels and the number and distribution of developed seeds and undeveloped ovules. The aggregate of fruits examined was 6,642, varying for the different lots from 22 for *M. fusca* to 1,200 for *M. Ringo sublobata*. *M. fusca* had small representation because but few fruits were available; all others had 100 or more fruits. The average weight for all fruits was 9.96 grams; if the two large crabs, Hyslop and Soultard, are eliminated, this average drops to 7.46 grams. Five of the forms had fruits which averaged less than one gram in weight, and four, besides the two crabs just mentioned, had fruits that averaged above 10 grams. As a means of giving a right impression of the range in size and form and the relative sizes of the different crabs, a single fruit of each of the twenty-five forms is shown, natural size, in Figs. 2 to 7, inclusive.

Table 9 gives the distribution of carpels, the seed distribution, and the percentage of ovules forming good seeds for each of the twenty-five crab-like forms.

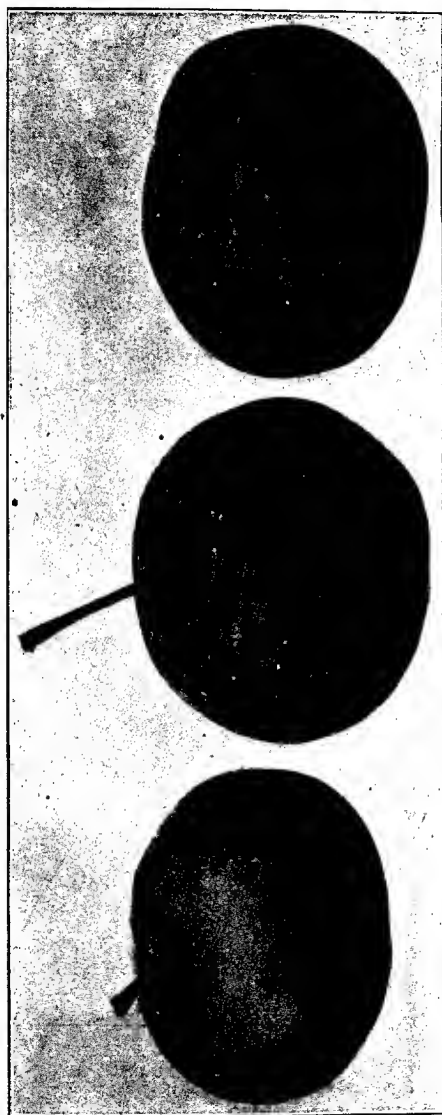


FIG. 2.—APPLES, NATURAL SIZE. LEFT TO RIGHT: *Malus Soudardi*, HYSLOP CRAB, *Malus Malus flore pleno*

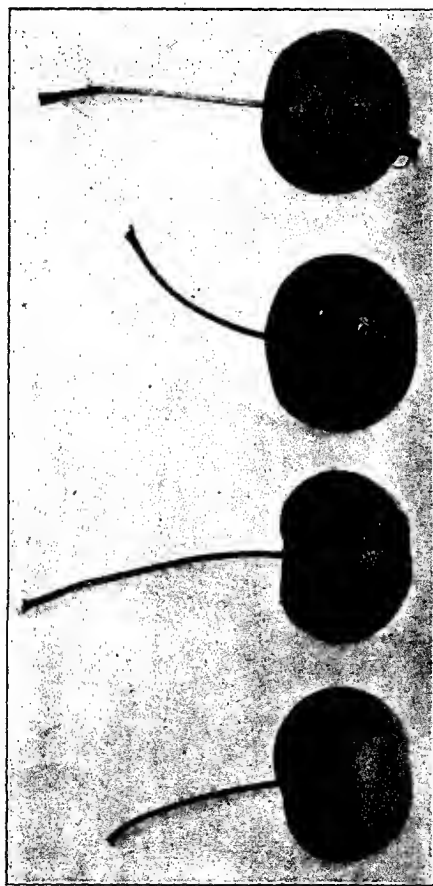


FIG. 3.—CRABS, NATURAL SIZE. LEFT TO RIGHT: *Malus baccata* (RED FRUIT), *Malus baccata* (RED FRUIT, LATE), *Malus baccata maxima*, *Malus prunifolia* var. (838)

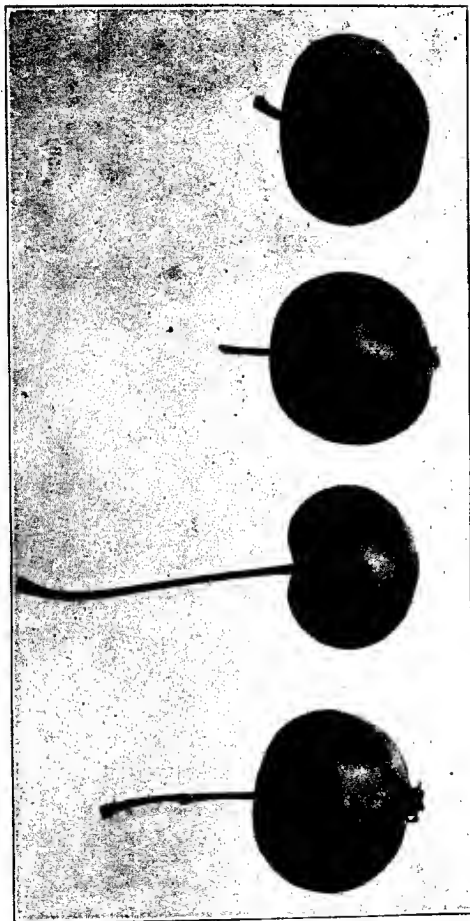


FIG. 4.—CRABS, NATURAL SIZE. LEFT TO RIGHT: *Malus prunifolia* var. (19651), *Malus Malus* var., *Malus Ringo sublobata*, *Malus microcarpa*



FIG. 5.—CRABS, NATURAL SIZE. LEFT TO RIGHT: *Malus Siberica*, *frutico coccinea*, *Malus Schiedeckeri*, *Malus spectabilis* No. 613, *Malus Rinna* (840), *Malus bruniifolia* var. (856)

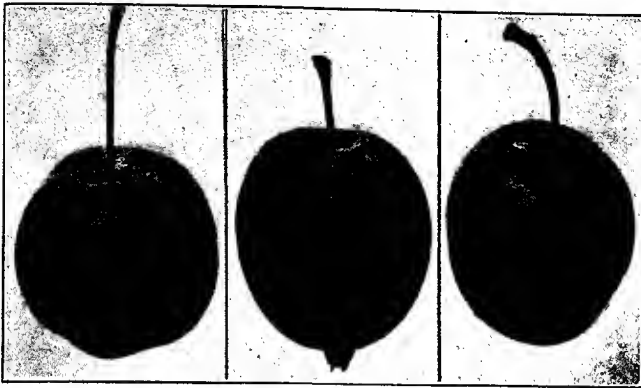


FIG. 6.—CRABS, NATURAL SIZE. LEFT TO RIGHT: YELLOW SIBERIAN CRAB (857), *Malus fastigiata bifera*, *Malus ioensis*

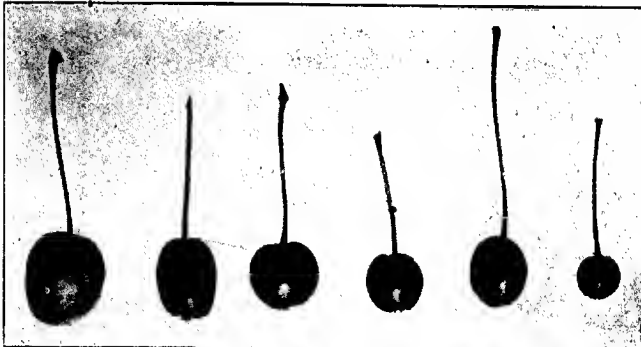


FIG. 7.—CRABS, NATURAL SIZE. LEFT TO RIGHT: *Malus Arnoldiana*, *Malus fusca*, *Malus floribunda*, *Malus Sargentii*, *Malus atrosanguinea*, *Malus Toringo* (19664)

NUMBER AND DISTRIBUTION OF CARPELS

There were wide differences among species in number and distribution of carpels; the range in numbers was from 2 to 12. The minimum of two carpels was found in two species, *M. Arnoldiana* and *M. Sargentii*. *M. Arnoldiana*, represented by 100 fruits, had two fruits each with two carpels; in both, the ovules were as expected, two in each cell; one developed three plump seeds, the other only one. *M. Sargentii*, represented by 223 fruits, had one fruit with only two carpels, containing four ovules; one good seed developed in each carpel. At the

other extreme *M. spectabilis* (No. 615) had one fruit with twelve carpels and another with eleven. In these two cases the large number of carpels was due to the appearance of a second whorl of carpels superposed upon the normal whorl. The fruit having twelve carpels had seven in the basal whorl and five in the upper whorl: these twelve carpels contained thirty-one ovules, ten of which developed into plump seeds, and of this ten, three were in the carpels of the superposed whorl. Nine other fruits had the additional whorl represented by one or two carpels and these carpels all contained developed seeds. The remaining 89 fruits of this species had carpels distributed as follows: 13 with the normal of five, 49 with six carpels each, 22 with seven, and 5 with eight each; but in all these fruits the additional carpels were crowded into the one whorl.

Those fruits possessing the secondary whorl of carpels gave external evidence of its presence in enlargements which appeared as protuberances projected vertically about the basin. These protuberances coincided with those carpels in which seeds were developed, and for those cases in which the seed development was distributed around the whorl, the calyx appeared as the bottom of a deep, irregular basin, while for those in which only one or two seeds, in close proximity, on one side, were developed, the resulting protuberance gave a one-sided fruit with the calyx appearing as if on the side of the apple. See central fruit in Fig. 5.

Two other species showed a strongly developed tendency to multiplication of carpels; these were *M. Malus flore pleno* and *M. Scheideckeri*. The first had 3 fruits with a maximum of nine carpels, 8 fruits with eight carpels each, 21 with seven each, 49 with six each, and only 19 with the normal five carpels. The second had a maximum of eight carpels, represented by one fruit; 82 fruits had each seven carpels, and 309, or 51.5 percent of the total of 600, had each six carpels. Two hundred and six fruits had each the normal of five carpels, and two fruits had only four carpels each. The range for the first species was 5 to 9, for the second, 4 to 8.

Considering the aggregate of 6,642 fruits representing the twenty-five crab forms, it appears that 4,565 fruits, or 68.73 percent, had each the normal five carpels. With numbers of carpels less than five there were 1,483 fruits, or 22.33 percent; and the aggregate of fruits with numbers of carpels above normal was 594, or 8.94 percent.

The two crabs with fruits of large size, Hyslop and Soulard, exhibited no departures from the normal of five carpels. All other crabs showed variation in numbers of carpels: twelve varied only in the direction of diminished numbers, four only in the direction of increased numbers, and seven showed variations in both directions.

The species bearing very small fruits tended more strongly to reduction in numbers of carpels than did the species having larger

fruits; for example, compare 100 fruits each of the four species *M. Toringo*, *M. Sargenti*, *M. floribunda*, and *M. atosanguinea*, whose fruits averaged less than one gram in weight, with equal numbers of the four forms *M. baccata* (red fruit), *M. baccata* (red fruit, late), *M. baccata maxima*, and *M. prunifolia* var. (838), whose fruits ranged in average weight from 6.62 grams to 9.63 grams. The distribution of carpels in these forms of *Malus* was as follows:

	NUMBER OF CARPELS			
	Three	Four	Five	Six
Small-fruited species	61	271	68	..
Larger-fruited species	1	7	391	1

For the small-fruited species 83 percent of the fruits had numbers of carpels less than five, while only 17 percent had the normal number. For the larger-fruited species only 2 percent of the fruits had less than five, 97.75 percent were normal, and one fruit, or $\frac{1}{4}$ of 1 percent, had one more than the normal of five.

While it was generally the case in this crab group that the very small fruits showed the greatest tendency to reduction in numbers of carpels, there were exceptions, as in the case of one variety of *M. prunifolia*, the 600 fruits of which had an average weight of 10.64 grams and in which 506 fruits, or 84.33 percent, had numbers of carpels less than five.

SEED PRODUCTION

The averages of seeds contained in fruits of the twenty-five species and varieties of *Malus* included in the list ranged from 1.32 for *M. fusca*, which was represented by only 22 fruits, and 2.02 for *M. atosanguinea*, represented by 100 fruits, to 7.8 for *M. Malus flore pleno*. For all forms considered together the aggregate of seeds produced was 28,050, which gives an average of 4.22 seeds to each fruit. The range shown was rather wide, and the general average decidedly lower than for the small fruits of orchard varieties. In distribution the range was from 0 to 14. There were 94 parthenocarpic fruits, representing nine of the species. Seventy-eight, or nearly 83 percent of these, occurred in the variety *sublobata* of the species *Ringo* (19689); the remaining 16 were found in numbers from 1 to 4 in eight other species. Fruits with one seed each numbered 574; these were distributed among nineteen of the species in numbers from 1 for *M. Ringo* and *M. Siberica frutico coccinea* to 312 for the variety of *M. Ringo*, which is so productive of parthenocarpic fruits. With two seeds each there were 1,037 fruits, with three seeds each, 1,130 fruits; this was the maximum frequency. Numbers for higher seed content decreased moderately at first and then more rapidly until the maximum of fourteen was reached by one fruit of *M. Malus flore pleno*.

This species had 2 fruits with thirteen seeds each, 6 with twelve seeds each, and 4 with eleven each. Four other species had one fruit each reaching a maximum content of eleven seeds. With ten seeds each, there were 65 apples, less than 1 percent of the total number of fruits examined. Eight species reached their maxima at ten seeds, and only five species had more than this number.

In *M. fusca* the highest number of seeds was three in each of two fruits, but the number of fruits of this species was too small to warrant the assumption that this maximum is normal. Next above *M. fusca* two species, *M. atrosanguinea* and *M. floribunda*, had the number five as the maximum of seeds produced; each was represented by 100 fruits; the former had one fruit, the latter three fruits, each of which had five seeds.

As with seed production in the orchard varieties, some of these crab forms tended to concentrate within a small range, as between 1 and 5 for *M. atrosanguinea* and *M. floribunda*, two closely related species; some tended to wider range, as 2 to 14 for *M. Malus flore pleno*, or 0 to 11 for *M. baccata* (red fruit) and *M. Ringo*. Some of the species had very small seeds, and in some the seeds were nearly as large as the average in orchard varieties. The size and shape of the seeds of the twenty-five crab-like forms are shown in Fig. 8 (natural size).

NUMBERS OF OVULES

It developed in examining the apples here considered that for most species the normal complement of two ovules to the carpel, or ten for an apple with five carpels, held with great regularity. In twelve of the species not a single departure in either direction from the expected normal was found. This group of twelve species contained 2,947 fruits which had an aggregate of 13,557 carpels and exactly double this number of ovules; each carpel had its full complement of two, no more and no less. Approximately one-half the ovules developed into seeds that appeared normal and viable; the seeds numbered 13,622, representing 50.24 percent of the contained ovules. The undeveloped ovules numbered 13,492, representing 49.76 percent of the total number; these were of all sizes, some so small as to require a hand lens for clear determination, others with integuments developed to nearly full size, but perfectly flat and containing no embryos. Nine other species had ovules in excess of the normal in numbers ranging from 1 to 300. The total of ovules above normal was 421 distributed in 158 fruits. Of this number 300 were found in fruits of *M. spectabilis* and 81 in fruits of *M. Malus flore pleno*, two species that are abnormal in most flower and fruit characters. Excluding these two species, the other seven species of this group had an excess above normal of 40 ovules distributed in 35 fruits.

M. spectabilis far exceeded all others in number of surplus ovules. This species had 300, or 71.25 percent, of the total surplus, and these

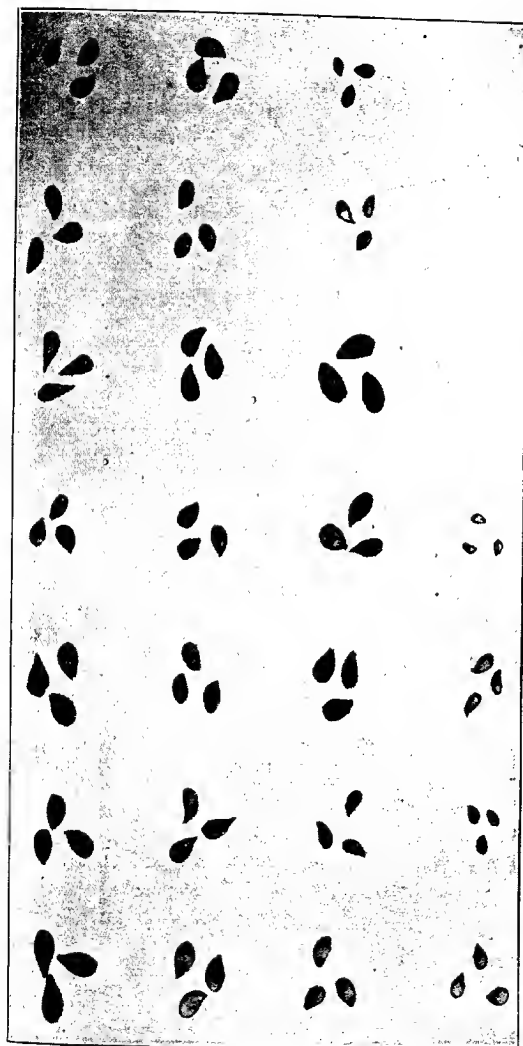


FIG. 8.—SEEDS OF MALUS FORMS INCLUDED IN THE CRAB GROUP. NATURAL SIZE. LEFT TO RIGHT: TOP ROW, *M. Soularde*, HYSLOP CRAB, *M. Malus flore pleno*, *M. baccata* (RED FRUIT), *M. baccata* (RED FRUIT, LATE), *M. baccata maritima*, *M. prunifolia* var. (838); SECOND ROW, *M. prunifolia* var. (19651), *M. Malus* var., *M. Ringo sublobata*, *M. microcarpa*, *M. Siberica fruticosa*, *M. Schiedacker*, *M. spectabilis* No. 615; THIRD ROW, *M. Ringo* (840), *M. prunifolia* var. (856), YELLOW SIBERIAN CRAB, *M. fastigiata bifera*, *M. Ioensis*, *M. Arnoldiana*, *M. fusca*, FOURTH ROW, *M. floribunda*, *M. Sargentii*, *M. atrosanguinea*, *M. Torringo*, dwarf, (19664)

were distributed in 91 of the 100 fruits examined in numbers varying from one to eleven.

The 81 surplus ovules in *M. Malus flore pleno* were distributed in 32 fruits in numbers ranging from one to six.

The maximum number of ovules was 25 in a fruit of *M. spectabilis* having seven carpels: four of the carpels contained 4 ovules each and three carpels had 3 each. The maximum for individual carpels was 5 ovules; this number was found in several cases in this same species. Where 4 or 5 ovules are present, they are arranged in two ranks along the placenta at the inner margin of the carpel.

In the four remaining species departures from the normal in the direction of decrease in numbers were recorded. These shortages were small; 16 for *M. Scheideckeri*, 6 for *M. Malus* var., 4 for *M. Sargentii*, and 2 for *M. Ringo sublobata*. This is a total of 28 below the expected total of 22,724 ovules for 2,244 apples having 11,362 carpels.

In two or three cases the two ovules of a single carpel were suppressed, but for all others one of the pair was absent or so undeveloped that its presence could not be detected.

The rarity of suppression of ovules is most clearly brought out by comparing the number recorded as suppressed with the total of ovules present. The 6,642 apples of all species contained 32,192 carpels, and with two ovules to each carpel, 64,384 would be the expected total of ovules. The actual number recorded as present was 64,777, but this included 421 ovules in excess of normal. Deducting this number leaves 64,356, which number, if increased by 28, the total of ovules suppressed, will equal the normal for the fruits considered. For the apples examined, approximately one ovule in 2,300 was suppressed; the percentage is sufficiently low to indicate that suppression is of rare occurrence.

COMPARISON OF ORCHARD AND CRAB-LIKE VARIETIES IN OVULE AND SEED PRODUCTION

In neither size-group of orchard varieties were deficiencies in ovule production recorded, but in all varieties, except Collins and Mammoth Black Twig in both size-groups and Tolman in the small size-group, ovules were in excess of normal in numbers ranging from two for Fameuse in the small size-group and three for the same variety in the large size-group, to 1,528 for Shockley in the large size-group and 1,468 for the same variety in the small size-group. The variety ranking next to Shockley in number of ovules in excess of normal was Winter Rambo, which had 878 in the large size-group and 334 in the small size-group, but this variety had more than three times as many large apples and nearly three times as many small apples as had Shockley, so that while there were 8.6 surplus ovules to each large apple in Shockley, there were only 1.6 surplus ovules

to each large Winter Rambo apple. For the small apples the difference between the two was still greater. In Shockley, multiplication of ovules appeared as a well-established characteristic, and in this regard the variety is comparable with *M. spectabilis* among the crabs. With other varieties whose fruits have surplus ovules, the numbers are scarcely sufficient to suggest an established tendency towards multiplication, but rather that their appearance is more or less casual. However, comparison of the records for the twenty-one orchard varieties (Table 7) with those for the twenty-five crabs (Table 9) indicates clearly that production of ovules in excess of the expected normal is of much more common occurrence among orchard varieties than it is among the crabs.

The relative standing of orchard varieties and the wild or semi-wild forms of *Malus* in the matter of seed production is, perhaps, most clearly shown by comparing the percentages of ovules, actually present, that develop into seeds. Thus, the 4,851 large fruits of twenty-one orchard varieties contained 53,319 ovules and developed 39,724 seeds, or 74.5 percent; the 4,726 small fruits of the same varieties contained 50,385 ovules and developed 33,940 seeds, or 67.38 percent; or, taking the aggregate of apples from orchard varieties, the percentage of seeds that developed was 71.03, while for the 6,642 fruits of species of *Malus* the 64,777 ovules developed 28,050 seeds, or 43.3 percent. These percentages of aggregates, 53.3 percent for species of *Malus* and 71.03 percent for orchard varieties, show fairly well the relative seed-producing capacity of the two groups and are sufficiently separated to indicate in a positive way that orchard varieties are decidedly superior to wild species in seed production.

SEED PRODUCTION UNDER CONTROLLED POLLINATION

All fruits thus far considered in relation to seed production have developed from flowers open to pollination by natural agencies. That the insect agents did the work well and that weather agencies were not adverse may be assumed from the fairly full crops borne by the trees.

The question as to whether protection of flowers and the artificial application of pollen gives equal or greater seed production than does open pollination is naturally suggested, and brief mention of seed production in fruits developed from protected hand-pollinated flowers may be made here.

The fruits resulting from hand pollination of emasculated flowers protected by paper bags numbered 4,504 for the six seasons 1909 and 1911-1915, but of these fruits there were 643 for which the record is, in some detail, incomplete; these are omitted, leaving 3,861 fruits, the records from which are here considered. These fruits were separated into four groups according to parentage for the purpose of maintaining a distinction between and recording the behavior of the two classes

of apples, orchard varieties and crab-like species of *Malus*, when crossed in different ways. At this time it is not the purpose to consider these combinations further than to show carpel and seed distribution and seed averages. The four classes of crosses were: orchard varieties \times orchard varieties, represented by 833 fruits; orchard varieties \times crab-like forms of *Malus*, represented by 857 fruits; crab-like forms of *Malus* \times orchard varieties, represented by 1,967 fruits; and crab-like forms of *Malus* \times crab-like forms of *Malus*, represented by 204 fruits. To these may be added 45 fruits resulting from self-pollinated flowers of crab-like forms of *Malus* and 12 fruits from selfed flowers of orchard varieties. These additional classes had small representation because most efforts to produce self-fertilized fruits have failed entirely. It is general thruout the genus *Malus* that stigmas of flowers of the very diverse forms do not readily accept their own pollen, and this characteristic is more commonly apparent among orchard varieties than it is among the less highly developed crab-like forms. As hybridity in plants tends strongly towards sterility, the prevalence of self-sterility in species and varieties of *Malus* indicates the probable hybrid nature of many of the forms. This, to the breeder, is a discouraging feature, because selfing is essential to determining the transmission and segregation of particular parental characters.

Records of carpel distribution with number and distribution of seeds for each of the classes of fruits resulting from controlled pollinations are brought together in Table 10. There is nothing in this table to indicate marked superiority in seed production of fruits developed from flowers artificially pollinated over fruits from flowers open to natural agencies for transfer of pollen. In the groups of naturally pollinated orchard varieties the average number of seeds to each fruit was for large fruits 8.27 and for small fruits 7.21, or for the two sizes combined, 7.85. For fruits from controlled pollinations, the 833 fruits of orchard varieties pollinated by orchard varieties had an average of 7.23 seeds to each fruit, and the 857 fruits of orchard varieties pollinated by crab-like species had an average of 7.45 seeds to each fruit; or, combining the two groups in which orchard varieties served as mother plants, the seed average was 7.35. These averages do not indicate that control of pollination exercised any marked influence upon seed content. Fruits of the twenty-five crab-like forms of *Malus* developed from open-pollinated flowers had an average of 4.22 seeds to each fruit. The 204 fruits of crab-like forms which resulted from hand pollinations with pollen from other crab forms had an average of 5.69 seeds to each fruit, while the 1,967 crab fruits developed from flowers hand pollinated with pollen of orchard varieties had an average content of 4.74 seeds to each fruit; or, combining these groups in which the mother plants are crabs, the average was 4.83 seeds to each fruit. Here the averages for fruits from con-

trolled pollinations are in advance of those for fruits from open pollinations, but the differences are not great, and when the disparity in numbers of fruits averaged in the different groups is considered, it appears that further investigation is needed before a stable basis for definite conclusions can be reached. It may be stated, however, that participation in the making and compiling of such records as we now have, together with study of the data, has given a rather definite impression that whether the pollination is open or controlled makes small difference in the proportion of ovules that develop as viable seeds.

CONCLUSIONS

1. From the foregoing study of seed production in apples it appears that the average number of seeds to each fruit is almost twice as great for orchard varieties as for fruits from crab-like forms of *Malus*. Dividing fruits of orchard varieties into two groups on the basis of size, it further appears that large apples exceed small apples in seed production, altho the difference is not nearly so great as is the difference in seed content between orchard varieties and crab-like forms.

2. The range in average seed production as exhibited by different varieties is wide with both orchard varieties and crab-like forms.

3. Departures from the normal of five carpels to each fruit occur with both orchard varieties and crab-like forms, but are much more frequent with crabs than with orchard fruits.

4. There are wide differences among individual varieties and species in seed-producing capacity, and the range in numbers of seeds in individual fruits is also wide.

5. The assumed normal of ten seeds to each fruit is likely to occur in a small percentage of orchard fruits, but rarely occurs in crab-like forms.

6. Capacity to produce seeds appears as a varietal characteristic.

7. Parthenocarpic fruits occur in orchard varieties and in species of *Malus*, but not in very great numbers.

8. There is great regularity in the appearance of ovules in normal numbers, that is, two in each carpel. Few cases of suppression of ovules occur; numbers in excess of normal are more common among orchard varieties than among crabs.

9. Comparison of seed production in fruits developed from flowers open to pollination by insects and in fruits from hand-pollinated flowers brings out only small differences; apparently seed production is not dependent upon the manner in which pollination is effected.

10. Considerable differences appear in seed production of individual fruits and of particular varieties, but averages of groups warrant the conclusion that the more highly developed orchard varieties exceed crabs in seed production and that, as between large and small fruits, large fruits produce the greater number of seeds.